ISSN 0704-3716

Canadian Translation of Fisheries and Aquatic Sciences

No. 5670

Distribution, abundance and biology of the northern bear shrimp (*Sclerocrangon boreas*) in the northwestern Bering Sea

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Original title: Raspredelenie, chislennost' I biologiya severnogo shrimsa-medvezhonka Sclerocrangon boreas v severo-zapadnoj chasti Beringova morya

In: Promyslovo-Biologicheskie Issledovaniya Morskikh Bespozvonochnykh, 1992, pp.68-77.

Published by: Vniro, Moskva, (Russia)

Original language: Russian

Available from:
Canada Institute for Scientific and Technical Information
National Research Council
Ottawa, Ontario, Canada K1A 0S2

2003

12 typescript pages

The northern bear shrimp *Sclerocrangon boreas* is widely distributed in the shelf zones of seas in the Northern Hemisphere, and is know as a circumpolar species that is encountered at depths of 10-250 m in all of our native arctic seas, in the northern Pacific Ocean, and off the coasts of Norway, Greenland and North America. It is an arctic-boreal species. Its southern boundary of distribution extends along the Sea of Japan [Kobyakova, 1936, 1937; Makarov, 1941; Vinogradov, 1950; Kudersky, 1960; Zarenkov, 1965a; Butler, 1980; Ortmann, 1895]. The literature deals mainly with questions concerning the systematics and biogeography of this species. The biological and ecological research is based mainly on material from European arctic seas [Kudersky, 1960; Menshutkina, Chaban, 1985]. Some investigations were devoted to the biological differences of genera from the family Crangonidae [Zarenkov, 1965b].

In this paper, the biology and distribution of the northern bear shrimp in the northwestern Bering Sea are examined on the basis of new data.

Material and Method

The material was collected during the summer-autumn of 1985-1988 in the northwestern part of the Bering Sea. The shrimp were caught with bottom trawls with a head line 27.5 or 34 m long with a 10-12 mm net inset in the sack. After each trawling, the temperature of the bottom layer of water was measured.

Biological analysis of the shrimp included the determination of sex, the inter-larval condition, the stage of ripeness of the females' eggs, the length of the carapace L_{car} and commercial body length L_{com} (from the posterior margin of the eye socket to the posterior margin of the carapace and from the posterior margin of the eye socket to the end of the telson respectively), as well as the weight of one individual or a group of several individuals of the same size with subsequent averaging of data. All measurements were carried out with accuracy up to 1 mm, and weighing – with accuracy up to 10 mg.

Due to the fact that various types of trawls were used during different years, the results of all the catches were converted to specimens/hectare using the formula

$$P_i = \frac{Ni}{vatq}(1 \cdot 10^4),$$

where P_i denotes stock density of the shrimp at i-th station, specimens/hectare; N_i – the catch during the i-th trawling, specimens/trawl; v – the speed of the vessel, m/h; a – the trawl opening, m; t – trawling time, h; q – trawl fishing efficiency = 0.5.

Results and Discussion

In the northwestern Bering Sea, the distribution of the northern bear shrimp is quite uneven. Its stocks are confined to the gently sloping parts of the bottom: at depths of 20-60 m in Litke Strait of the Karaginski Gulf, at 20-150 m off the Koryak coast from Natalya Bay to Cape Navarin, and at depths of 15-70 m in Anadyr Gulf from the Anadyr liman to Provideniya [Providence] Bay (Fig. 1).

In the Karaginski Gulf, the density of northern bear shrimp stocks amounts to 3-720 (average 94) specimens/hectare. Maximum density is noted in Litke Strait at depths of 30-50 m. Earlier, B. G. Ivanov [1975] noted accumulations of this species (catches up to 50 kg in 30 min of trawling) in the northern part of Karaginski Gulf, predominantly at a depth less than 30 m.

In Olyutorski Gulf, only single specimens of the northern bear shrimp were found in the catches. During our observations, this species did not form dense stocks, though it was spread over a large area.

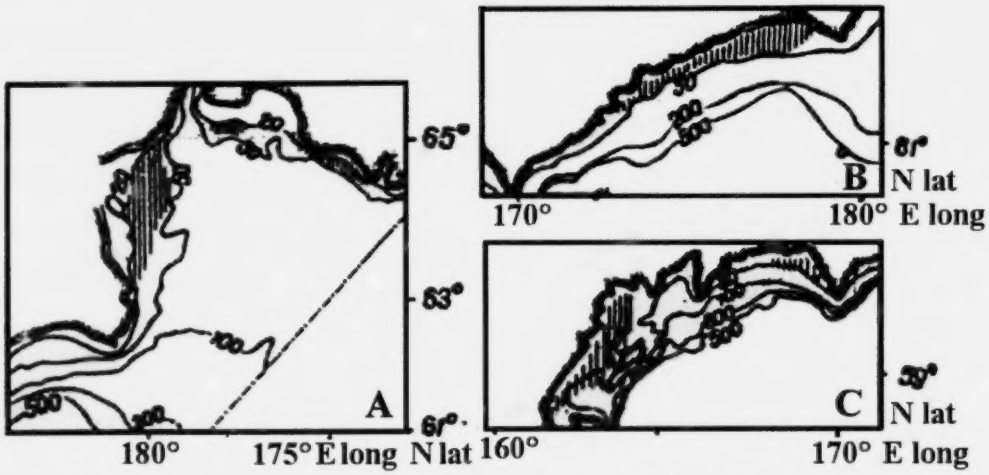

Fig 1. Distribution of the northern bear shrimp (shading) in the Anadyr Gult (A), off the Koryak coast (B), and in the Olyutorski and Karaginski gulfs (C)

Fig. 2. Distribution of the northern bear shrimp in the vicinity of the Koryak coast in August-September (A), October (B) and November (C): 1 - 3-50, 2 - 51-200, 3 - >200 shrimp per hectare

In the Koryak coastal area, the density of its stocks was somewhat lower. It increased from 3 to 470 specimens/hectare south to north within this area. The maximum density in summer was also noted around Cape Navarin at depths of 20-30 m.

In Anadyr Gulf, the stocks of the northern bear shrimp are more dispersed. The maximum density here reached 211 specimens/hectare around Provideniya Bay, and averaged 26 specimens/hectare for the entire gulf.

The differences in the density of shrimp stocks in the different areas are probably due largely to the productivity of these areas. Karaginski Gulf is one of the most

productive areas of the Bering Sea [Lus, Kuznetsov, 1961; Dulepova, 1985; Nadtochiy, Bukin, 1986], which creates a good food base for shrimp. This definitely contributes to the formation of more dense stocks. At the same time, the total biomass of this shrimp amounts to 600 tons in Karaginski Gulf and 1200 tons on the Koryak shelf, which is due to the size of habitat area. In Anadyr Gulf, its biomass is minimal – 500 tons.

The changes in the location of dense stocks of this species can be used to characterize the previously noted migrations of the northern bear shrimp off the Koryak coast [Bukin, 1988]. In August-September, it was not encountered at depths greater than 60 m and the density of its stocks increased shoreward, reaching its maximum at depths of about 20 m (Fig. 2, A). In October, the nucleus of the population was found at depths of 40-50 m and the lower boundary of distribution moved down to 70 m (Fig. 2, B). In November, these shrimps move completely away from the coastal zone: the upper and lower boundaries of distribution move down to 40 and 150 m respectively (Fig. 2, C). At the same time, its population density drops by an order of magnitude to 3 specimens/ha, i.e. the shrimp disperse. Thus, these data do not support the opinion of B. G. Ivanov [1975] who maintained that this species did not migrate.

Although the northern bear shrimp in a fairly wide range of temperatures, it optimal temperature is 3-4°C [Menshutkina, Chaban, 1985; Bukin, 1987]. The investigations of 1988 have added to our data and explained some of the behavioral characteristics of these shrimp.

The temperature dependence of the distribution of female shrimp with gonads and eggs at various stages of ripeness is the most manifest (Fig. 3, A, B). Females after extruding larvae were encountered mainly at minus temperatures of the water. The optimal temperature for the ripening of external eggs is 1.5-3.0°C. For ripening of internal eggs, the temperature should be even higher, and still higher for the earlier stage of ripeness ("internal white eggs"). We separated the female shrimp without eggs into sexually mature specimens (with a body length over 75 mm) that could already deposit external eggs, and sexually immature females of smaller sizes. The mature females show a preference for low temperatures (less than 0°C), while immature females are encountered at –1.5 to –1.0°C, and also at 4.5-6.0°C.

In October-November, the start of migrations of this species to the depths coincides with a drop in water temperature. At this time, most of the females have internal green eggs and new external eggs. One can assume that water temperature is the main factor determining the distribution of different-sized groups, as it affects the maturation of the gonads. In this case, the noted migrations of the shrimp to the depths have to do with the search for optimal temperature by the largest group of females during this period.

The shrimp off the Koryak coast are smaller than in the Karaginski and Anadyr gulfs of the Bering Sea (see table). Body size changed insignificantly from year to year. The smallest sizes in all the areas were noted in 1986.

Regular studies on the northern bear shrimp were conducted only in the Koryak coastal area. Compared with 1978, the sizes of the shrimp here have decreased over the past years (Fig. 4). The highest number of small shrimp (up to 70 mm) was observed in 1986, after which it dropped drastically.

The presence of a peak in the abundance of shrimp with L_{com} = 80-100 mm is noteworthy. This peak was observed over a number of years. Such constancy may be due either to uniform yearly recruitment in the population (there is no alternating of strong and weak year-classes), or to trawl selectivity that results in catches of mainly one size group.

The sex composition of the northern bear shrimp was determined in 1988. It was found that the males were much smaller than the females (average L_{com} = 55.7 and 79.3 mm respectively). This tells on the sex composition of the catches (one male to every seven females), as trawl efficiency is significantly lower for small individuals. If we compare the male/female ratio of only small groups corresponding to the size range of the males, the sex ratio levels out considerably (1:2). For shrimp with $L_{com} < 50$ mm, the sex ratio changes in favor of the males (2:1). The actual sex ratio in a population is probably close to 1:1, but because females are larger than males, this ratio is distorted in favor of the females.

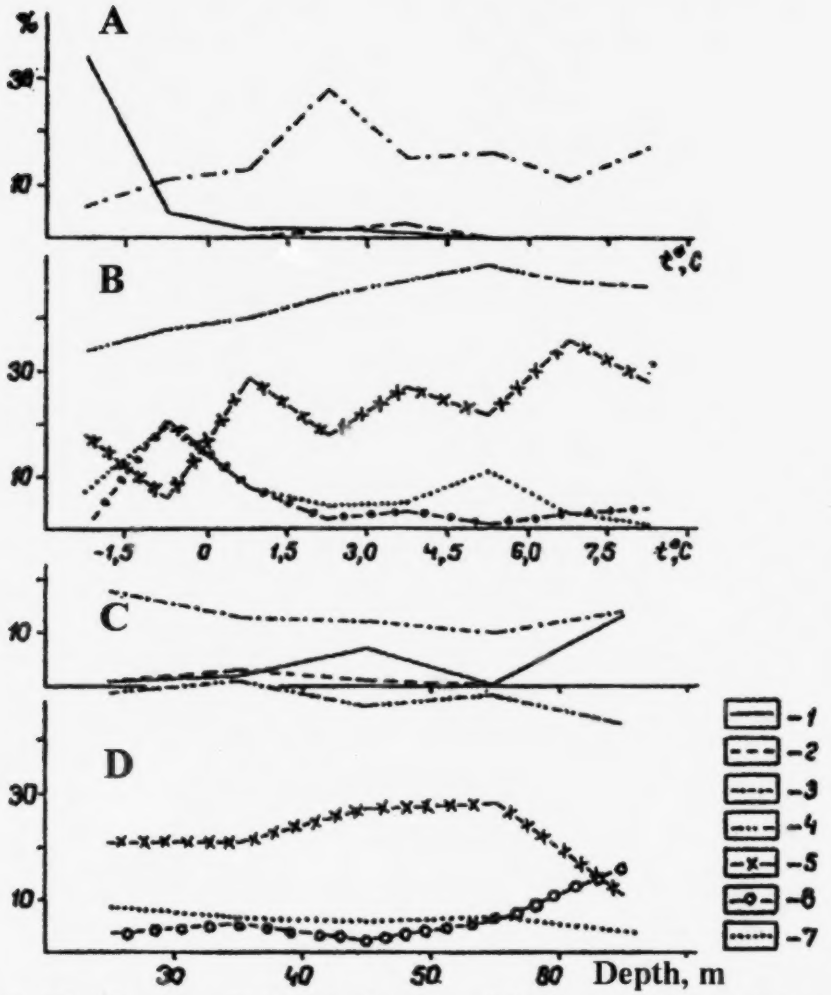

Fig. 3. Distribution of biological stages of the northern bear shrimp in the Bering Sea depending on temperature (A, B) and depth (C, D): 1 - females, larvae extruded; 2 - females, eggs with eyes; 3 - females, eggs green; 4 - females, inside green; 5 - females, inside white; 6 - females, without eggs, mature; 7 - females, without eggs, immature

Size characteristics of the northern bear shrimp by area and year, mm

Year	Anadyr Gulf			Koryak coast			Karaginski Gulf		
	$\bar{x}$	δ_{n-1}	$\frac{x_{min}}{x_{max}}$	$\bar{x}$	δ_{n-1}	$\frac{x_{min}}{x_{max}}$	$\bar{x}$	δ_{n-1}	$\frac{x_{min}}{x_{max}}$
1978	-	-	-	88.9	16.9	$\frac{41}{145}$	-	-	-
1985	-	-	-	82.1	16.7	$\frac{52}{126}$	-	-	-
1986	-	-	-	73.4	15.3	$\frac{41}{108}$	78.5	17.6	$\frac{40}{115}$
1987	-	-	-	82.4	14.5	$\frac{30}{108}$	-	-	-
1988	81.5	14.6	$\frac{44}{116}$	79.3	12.3	$\frac{27}{110}$	82.6	11.8	$\frac{34}{117}$

Note: the minus (-) sign denotes absence of data

With an increase in depth, the percentage of males increases from 12 to 21% (Fig. 5, A). However, the number of large males (over 55 mm) increases even more rapidly: from 1/3 of all males at a depth of 20-30 m to 100% at a depth of more than 60 m.

At minus temperatures (from 0 to –1.6°C), males comprise from 15 to 36% of all the shrimp, and 90% of them are large (Fig. 5, B). The smallest number of large males was noted at a temperature of 3-4°C. The reason for this kind of distribution of males requires further investigation. Mating probably occurs at minus temperatures and that is why the large (sexually mature) males stay at these temperatures.

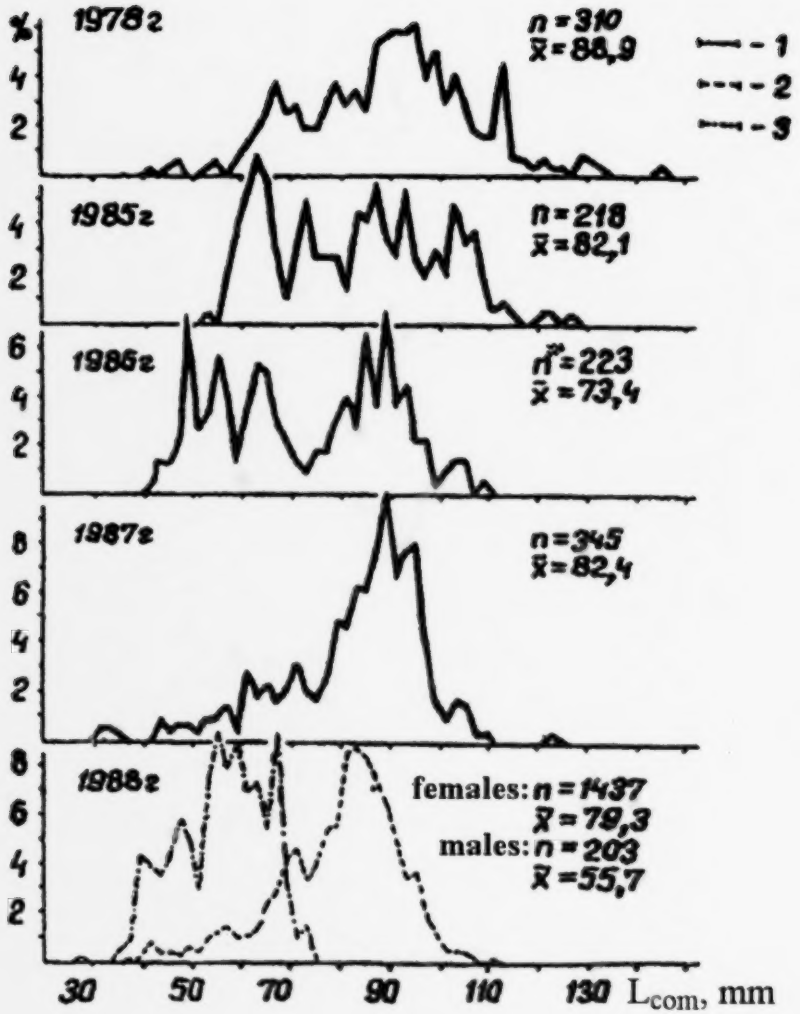

Fig. 4. Size composition of the northern bear shrimp of the Koryak coast during different years:
1 - males and females; 2 - females; 3 - males

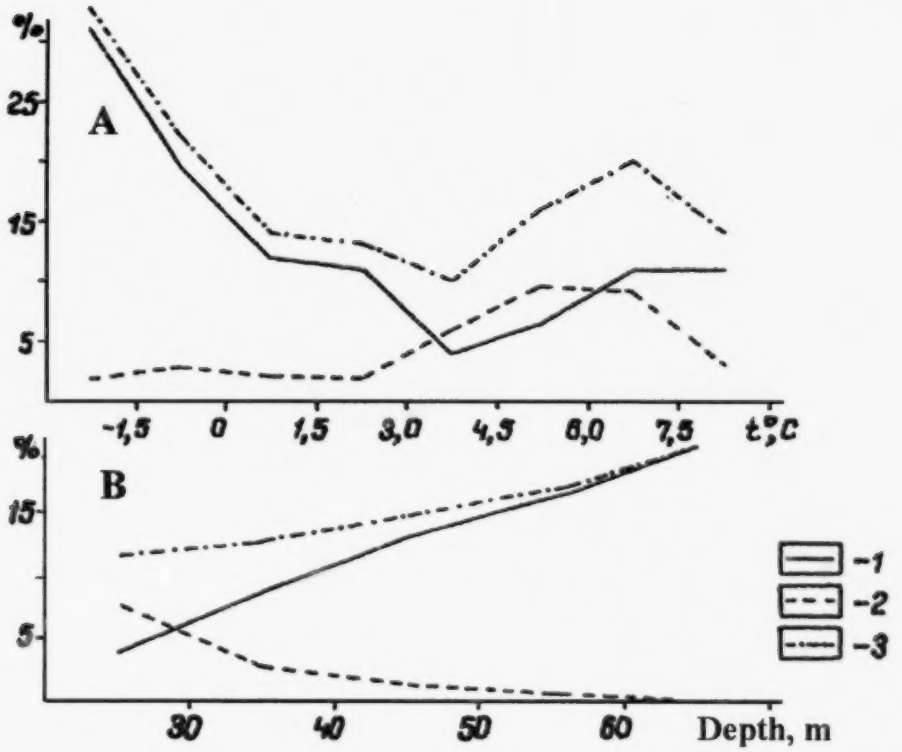

Fig. 5. Biological status of males of the northern bear shrimp
in the Bering Sea depending on temperature (A) and depth (B):
1, 2 - large males (over 55 mm) and small males respectively; 3 - all males

Summary

1. The northern bear shrimp is encountered in all the areas of the northwestern Bering Sea, but forms stocks in relatively small areas of a gently sloping bottom.
2. The highest population density (720 specimens/hectare) is observed in Karaginski Gulf, and the highest biomass (1200 tons) – on the Koryak shelf.
3. No significant fluctuations in the abundance of shrimp were observed in 1986-1988.
4. The males of the northern bear shrimp are much smaller than the females. The sex ratio in a population is close to 1:1.

5. With the development of the gonads and external eggs, the females select a specific water temperature. The extrusion of larvae and the fertilization of new eggs take place at a minus temperature of the water.

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